ISTENER
Ingeniería de Sistemas Térmicos y Energéticos

UNIVERSITAT JAUME I

Rank®

ORC based CHP unit as active technology for reducing CO2 emissions in public buildings (BRICKER Project)

Prof. Joaquín Navarro Esbrí
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Rank® founding partner

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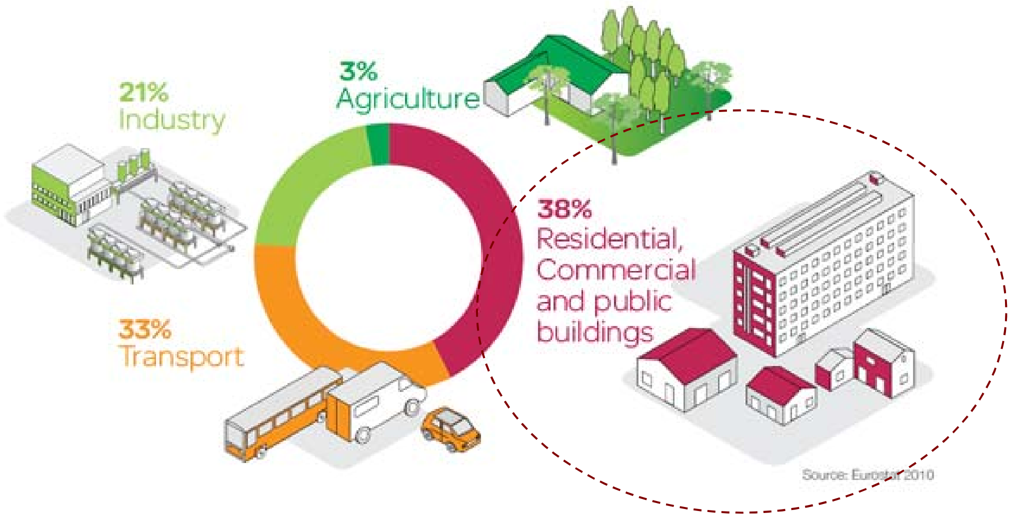
The global contribution from buildings towards energy consumption has steadily increased reaching near 40% in developed countries. Buildings in EU27 Member States are responsible for 40% of Europe's energy consumption and 36% of CO2 emissions.



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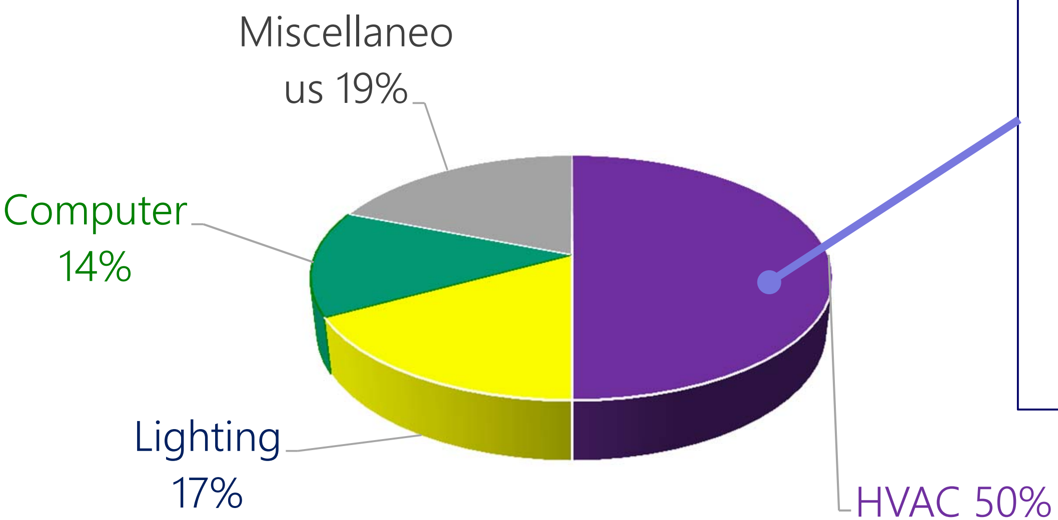

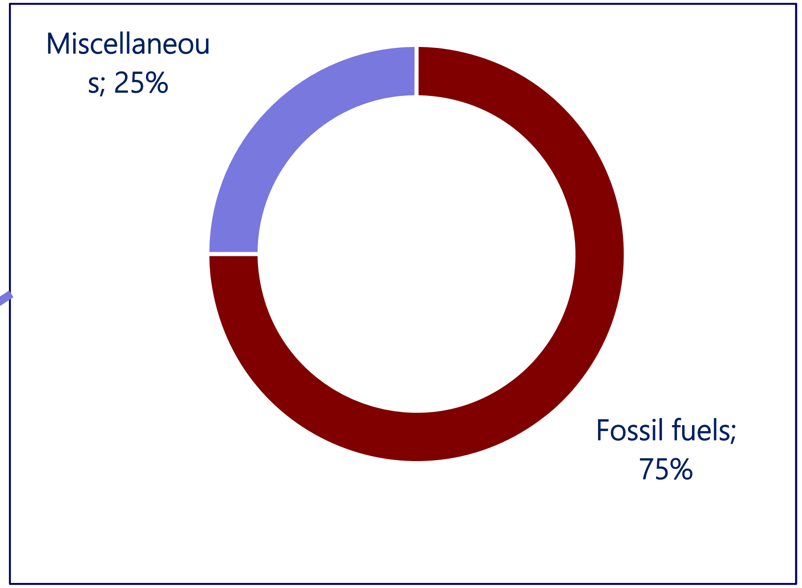

BRICKER

ENERGY REDUCTION IN PUBLIC BUILDING STOCK

BRICKER aims to develop a retrofitting solution package for existing public-owned non-residential buildings in order to achieve a drastic reduction of the energy consumption (beyond 50%) and of the CO_2 emissions. It is proposed that this goal is achieved by:

- Reducing the building demand with envelope retrofitting
- Implementing zero emissions energy production technologies based on a cogeneration system fed with locally available and clean renewable sources.
- And integrating and developing operation strategies for the BRICKER Technologies and guidance for design, commissioning and maintenance

BRICKER

ENERGY REDUCTION IN PUBLIC BUILDING STOCK

The retrofitting solution package is implemented in two real demonstration buildings, located in different climate conditions in two different countries and with different end-uses: health and higher education facilities.

Engineering college located in Liège

University hospital located in Aydin

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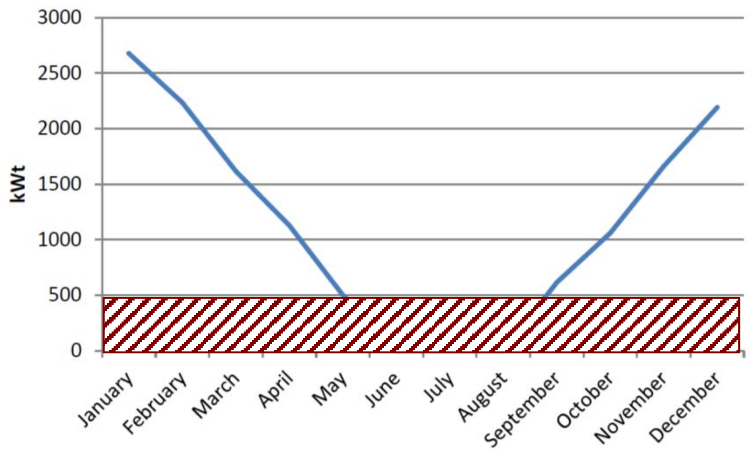
Engineering college located in Liège

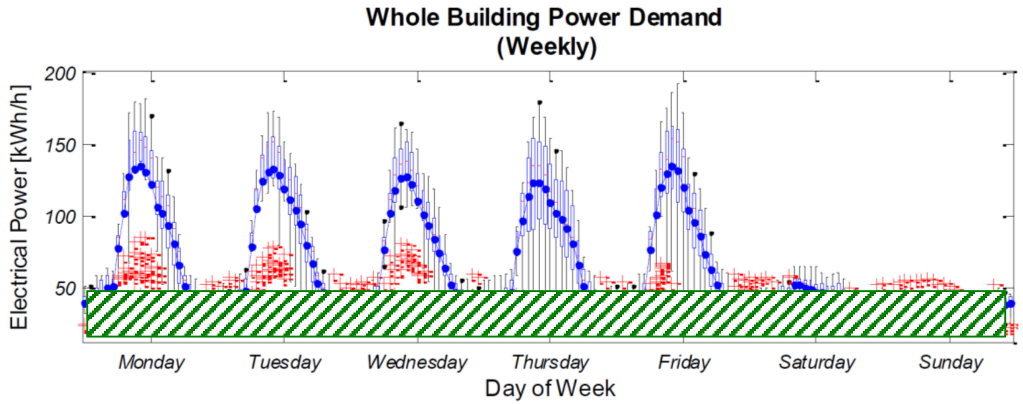


Monthly heating demand (2012)

HEATING DEMAND

Month	Energy [kWh]	Power [kWt]			Days with demand
		Average	Maximum	Minimum	
January	407,106	2,678	6,298	1,701	16
February	424,409	2,234	3,504	1,592	20
March	352,869	1,615	2,875	1,111	23
April	214,379	1,128	2,112	368	20
May	109,195	500	1,621	105	23
June	0	0	0	0	0
July	0	0	0	0	0
August	0	0	0	0	0
September	122,698	615	1,224	178	21
October	221,549	1,060	2,120	221	22
November	347,054	1,661	2,952	761	22
December	333,123	2,192	3,860	1,312	16
Total	2,532,382	1,457	6,298	105	183

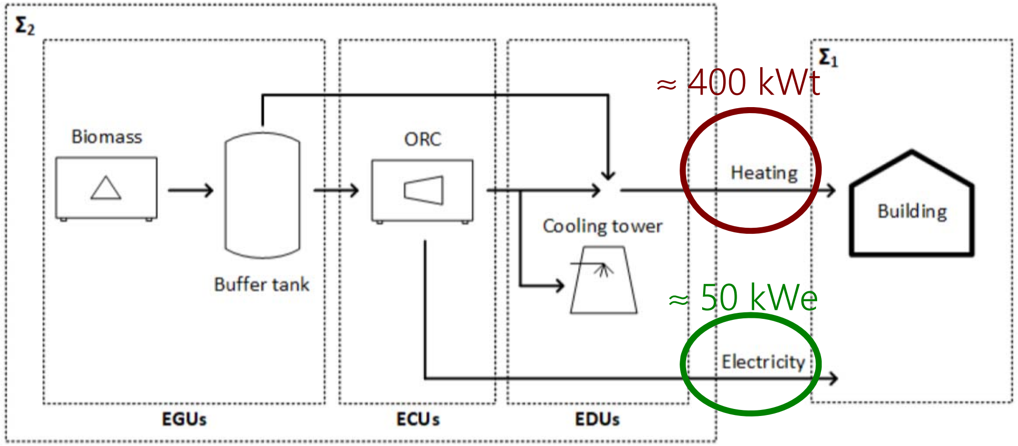
Engineering college located in Liège



ELECTRICITY DEMAND

Month	Average of annuities 2010, 2011 and 2012 [kWe]		
	Day	Night	Weekend
January	185	98	64
February	190	104	54
March	177	102	55
April	164	96	39
May	166	87	88
June	104	58	26
July	46	27	20
August	79	63	20
September	155	90	36
October	171	93	53
November	176	98	44
December	181	98	52

Engineering college located in Liège



TECHNICAL REQUIREMENTS

Only electricity and heating are considered.

- ORC should be activated using biomass and work as many hours as possible in best global efficiency operating point
- So, the equipment must be designed to attend the base heating demand in the form of hot water between 60 and 80ºC
- The equipment must satisfy as much as possible the base of the electrical demand

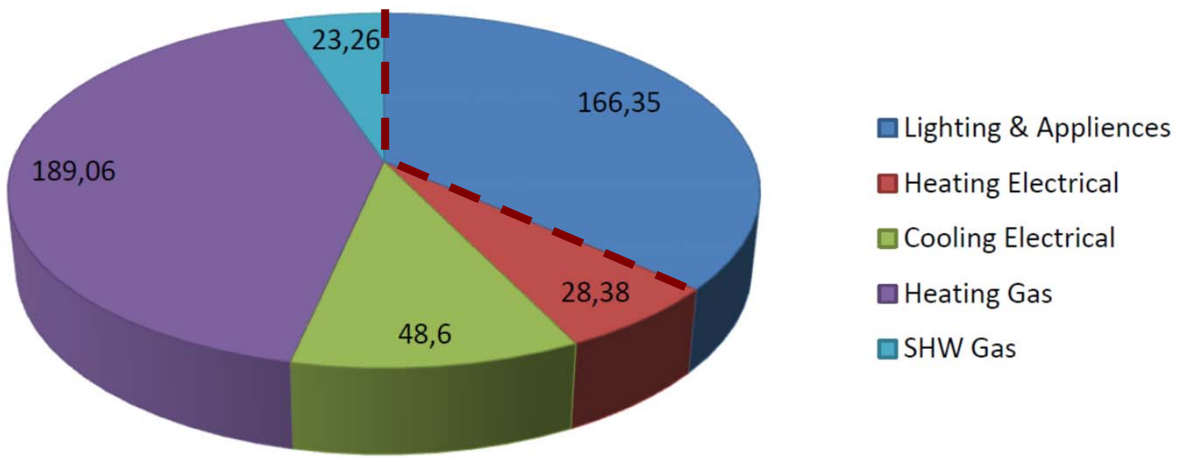
University Hospital located in Aydin

The final energy demand for heating and cooling amount to 87.4 kWh/(m2y) and 28.2 kWh/(m2y), respectively

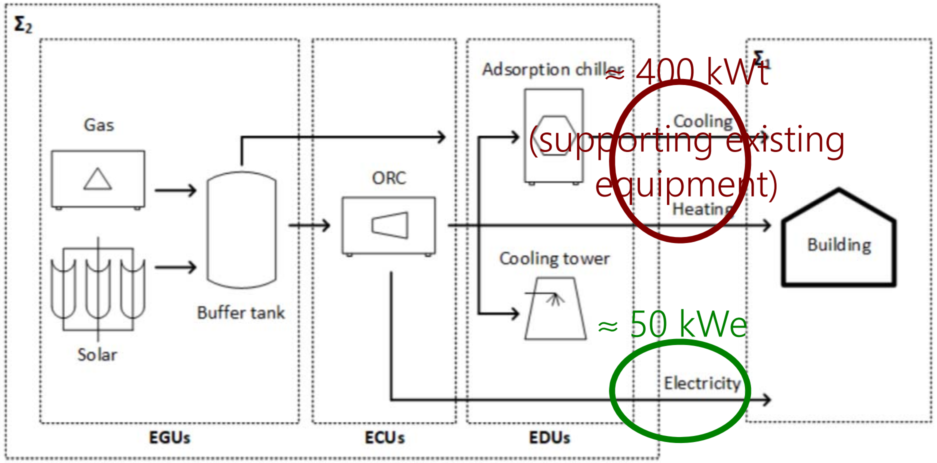
- 13,000 kWt Natural gas boilers installed for heating and SHW
- 10,000 kWt centrifugal chiller for cooling demand

The primary energy content for heating is due to gas consumption, while for cooling is associated to electricity consumption.

ELECTRICITY, HEATING AND COOLING DEMAND



University Hospital located in Aydin

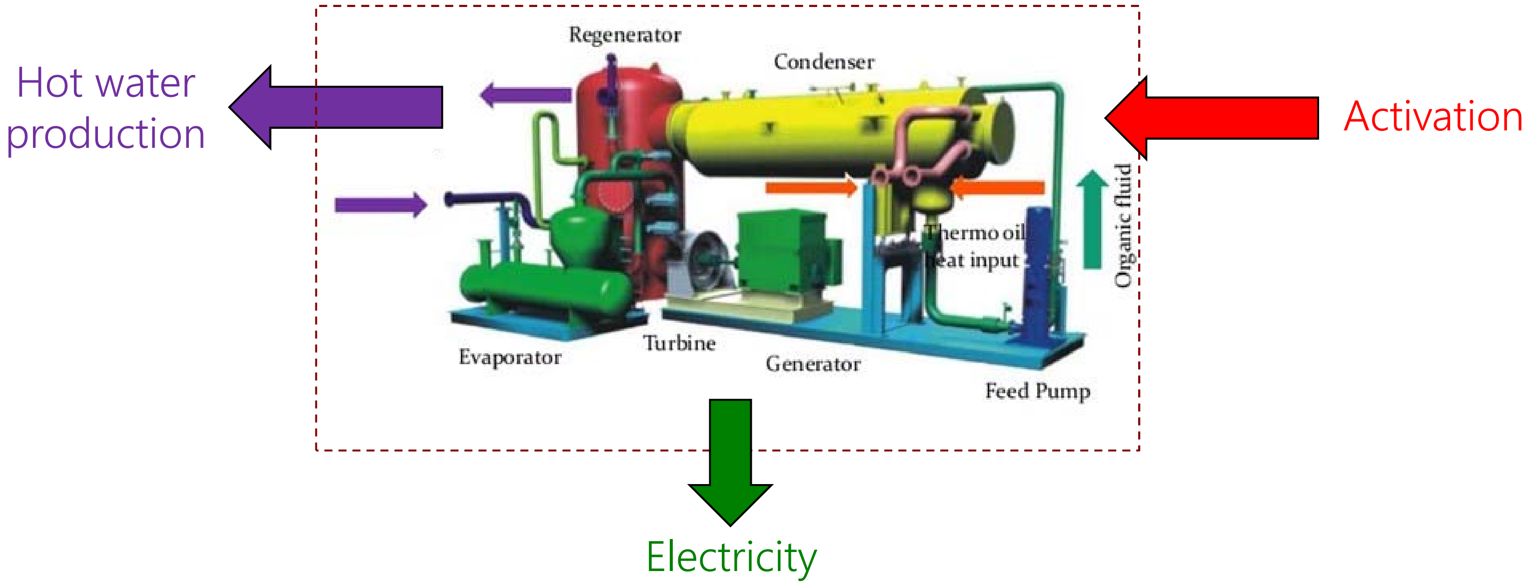


TECHNICAL REQUIREMENTS

Due to the importance of the refrigeration, it has been also included in the CHP requirements and the CHP unit will contribute to the electricity, heating and cooling demand (using and adsorption chiller).

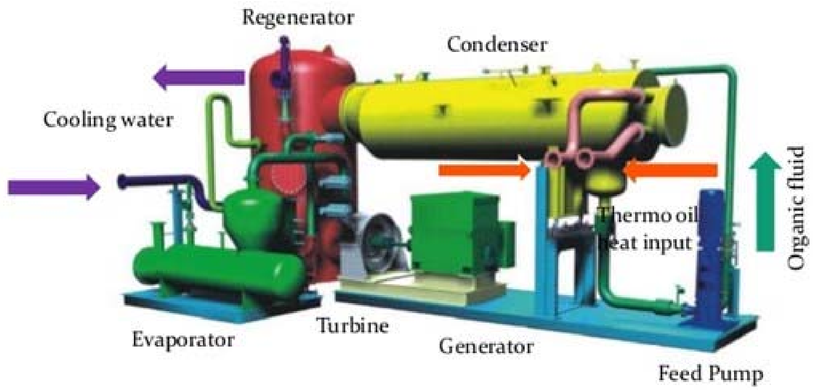
Because of the size of the hospital building, the contribution provided by the BRICKER system will only cover a small part of the total load of the building. Therefore, the existing system and the BRICKER system will be operated jointly and the CHP unit requirements are taken from Liège.

- Due to the climate conditions, the ORC should be solar activated.
- So, being solar activated, the equipment should contribute as much as possible to the electricity, heating and refrigeration demand, depending on the power supplied by the solar collectors.



CHP TECHNICAL REQUIREMENTS

- Activation with low temperature (compatible with solar collectors technology → about 250ºC)
- Net electricity production about 50 kW (compatible with electricity consumption base in Liège)
- Hot water production between 60 and 80 ºC (about 400 kW, compatible with heating consumption base in Liège)



DESIGN

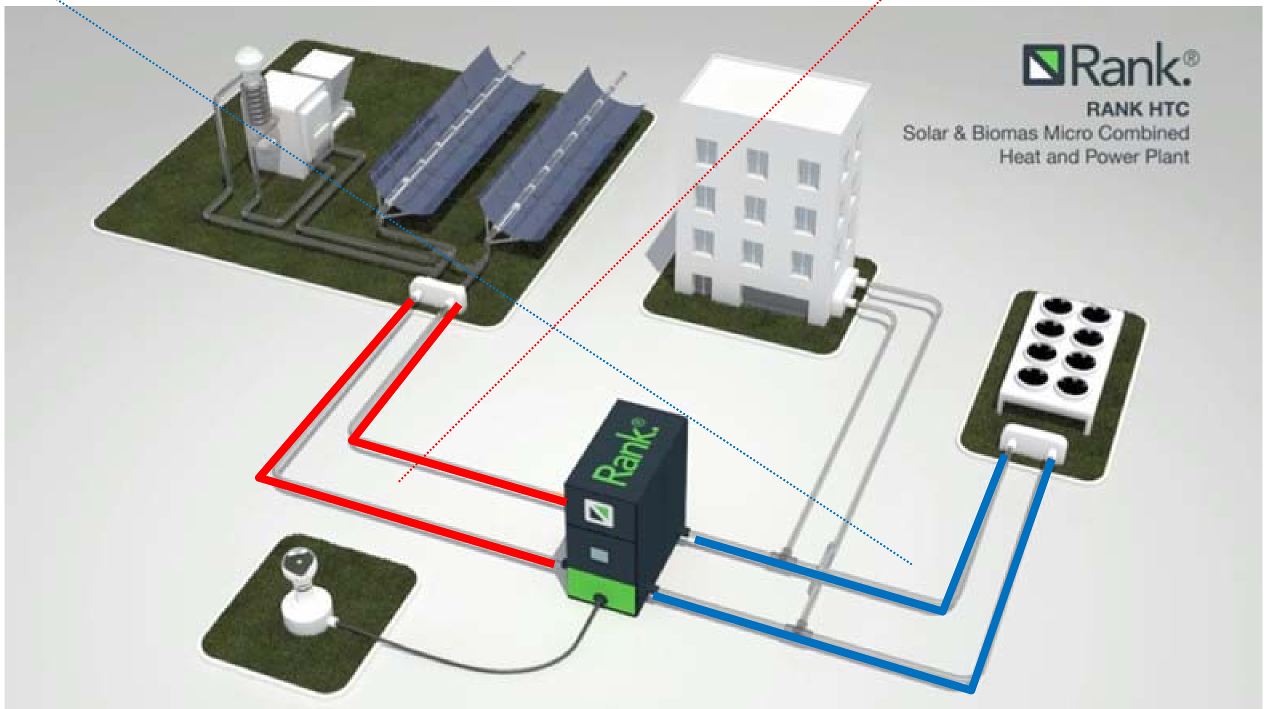
Once the technical requirements of the ORC are defined (CHP unit solar/biomass activated producing electricity and hot water), the ORC design must be addressed attending the selection of:

- Heat transfer fluids
- ORC working fluid
- Cycle configuration
- Components technology

Heat transfer fluids

The heat transfer fluid selected for the activation loop has been thermal oil. The possibility of using steam or pressurized hot water as heat transfer fluid has been rejected.

Water is the fluid that is heated at the ORC condenser for attending the heating or cooling demand (through an adsorption chiller)

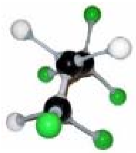


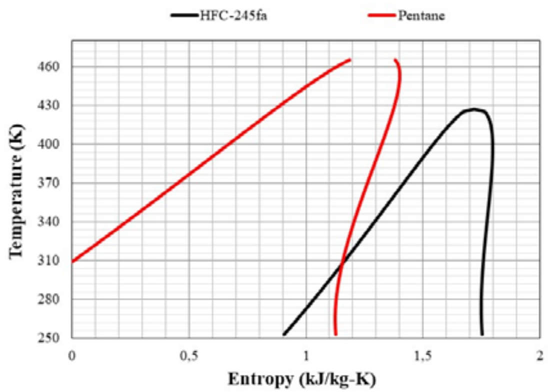
ORC working Fluid

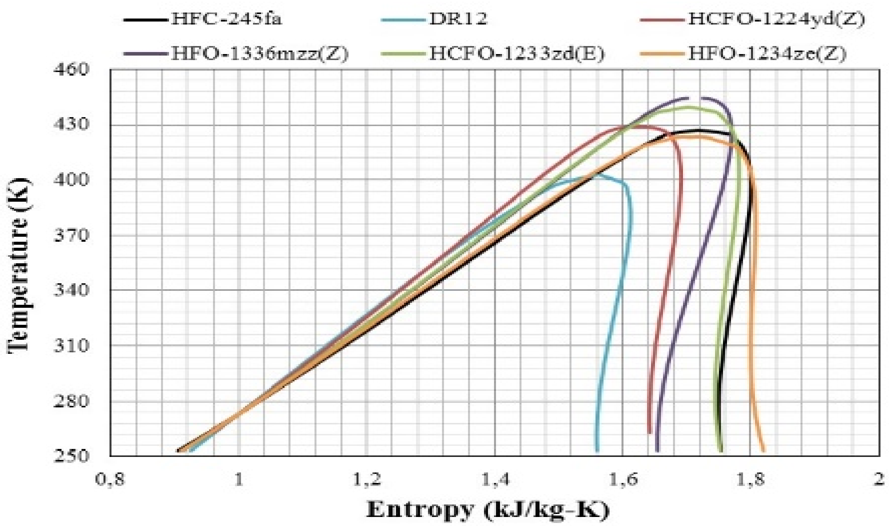
Regarding the working fluid selection, special attention has been taken in security properties, as toxicity and flammability, thermal stability and environmental properties.

Fluid	Toxicity/Flammability	GWP	ODP	Tcrit (ºC)	Pcrit (bar)	Tmax (ºC)
Isopentane	600/Flammable	11	0			
R245fa	400/Non-flammable	950	0	154	36.51	250
R1233zd(E) - HCFO	800/Non-flammable	1	~0	165.6	35.71	200
R1336mzz(Z) - HFO	500/Non-flammable	2	0	171.3	29	250
SES36	1000/Non-flammable(*)	3710	0	177.55	28.49	190

HFC-245fa

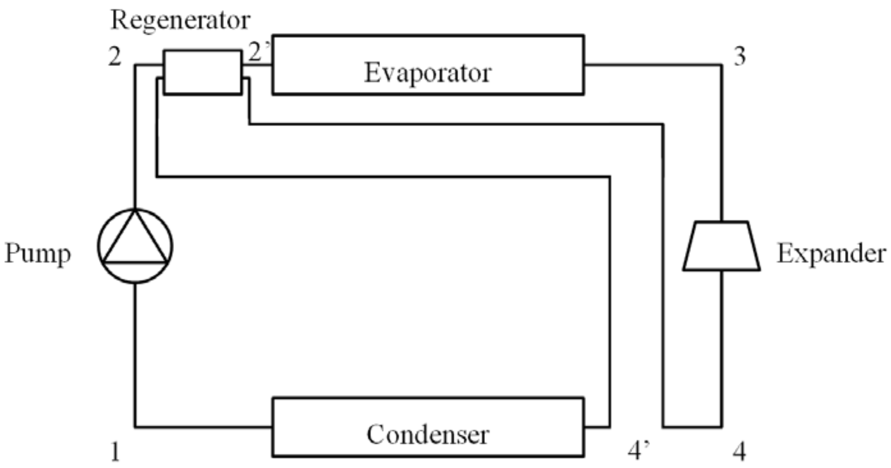


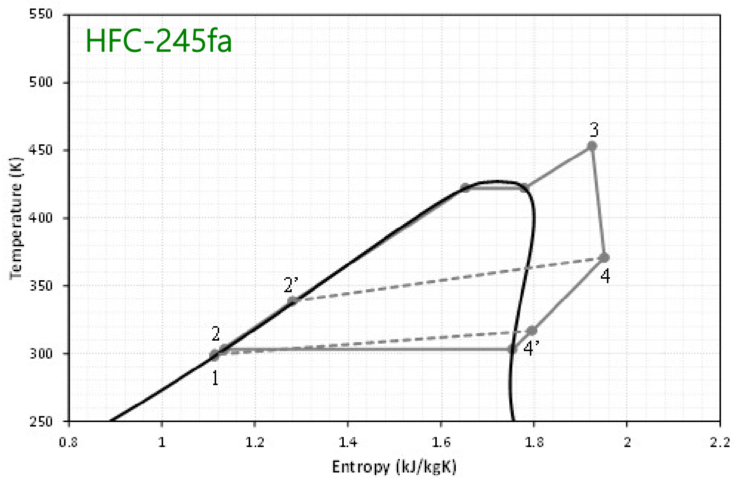




Cycle configuration

Attending to the ORC configuration, a regenerative cycle has been adopted in subcritical conditions, limiting the maximum temperature to 250ºC.

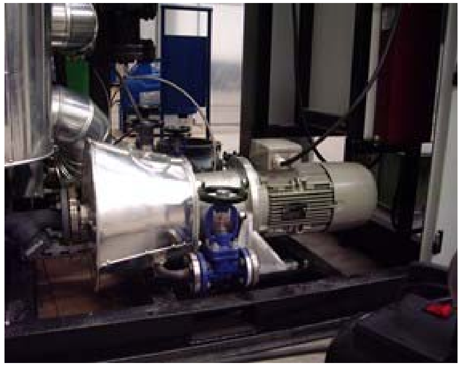




Components and technology adopted

- Compact brazed plate heat exchangers
- Volumetric expander
- ORC pump

ORC Expander prototype



ORC Pump prototype

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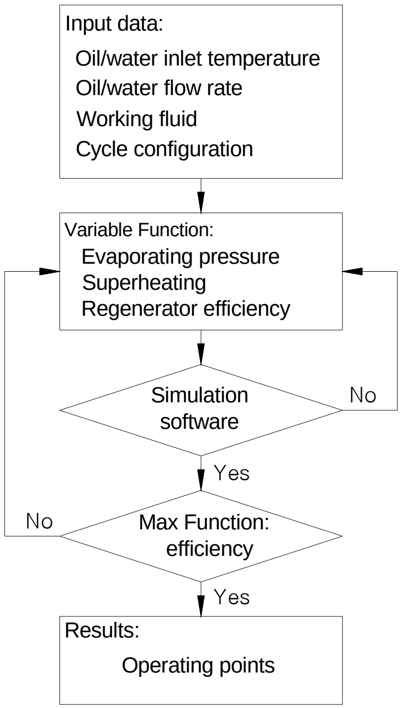
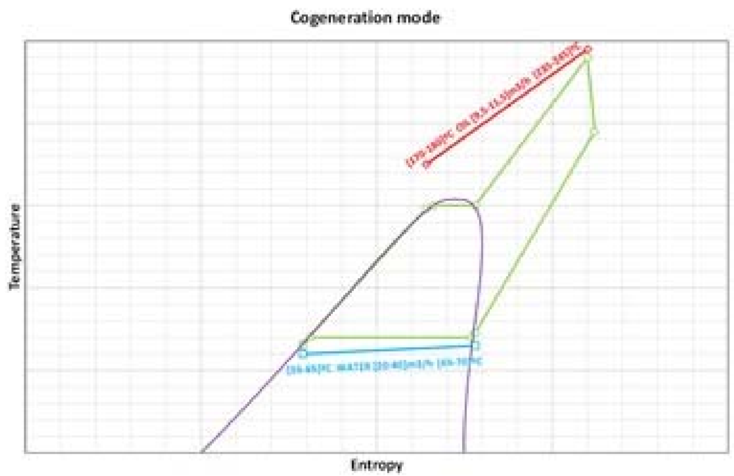
Simulation software

Using estimated efficiencies for expander and pump, a simulation software has been used to optimize the performance in the desired operating point (considering the regenerative configuration activated up to 250ºC and producing hot water between 60 and 80ºC).

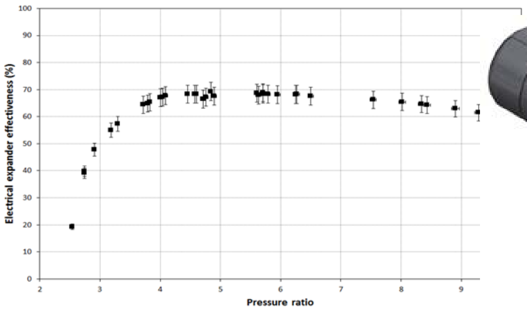


Evaporating pressure, the superheating and the regenerator efficiency have been optimized in order to reach the maximum efficiency.

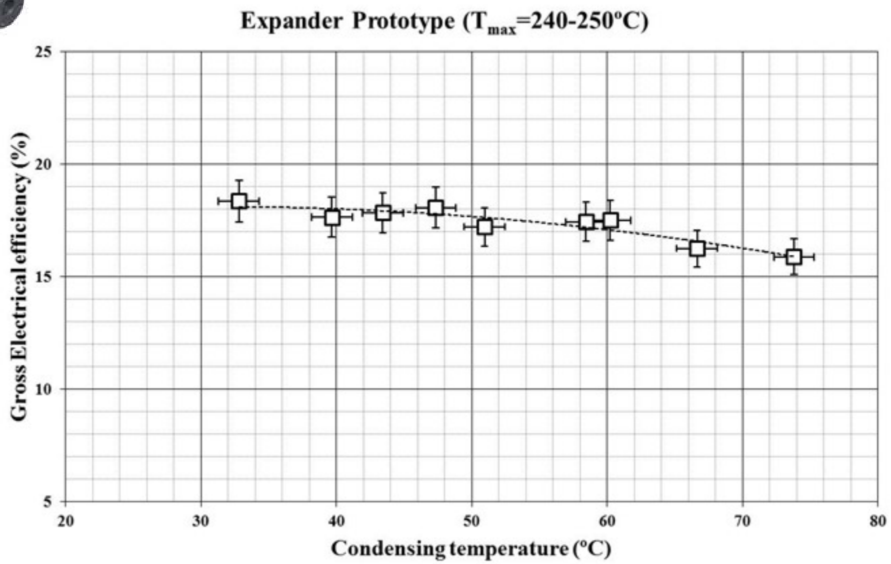


ORC scaled prototype

On the other hand, an ORC scaled prototype (1:3) has been constructed to optimize the design. In this way, the experimental results are used to feedback the optimization software and tune the final design.



Finally, the expander prototype has been designed according to a high efficiency system in cogeneration mode



ORC scaled prototype

With the final designs of the components, a test accumulating operating hours is carried out.

- Good performance results are obtained
- Degradation has been observed

Maximum temperature limited to 225ºC

ORC prototypes

Three CHP prototypes have been constructed, tested and optimized (control parameters adjusted), and finally installed in the demo sites (2 units in Turkey and 1 unit in Belgium)

ORC prototypes

Partial load tests

	Test 1	Test 2	Test 3	Test 4
Thermal oil inlet temperature (ºC)	206	217	203	210
Thermal oil outlet temperature (ºC)	133	155	143	143
Thermal oil flow rate (m^3/h)	10	10	12	10
Thermal oil thermal power (kWt)	410	380	415	408
Water inlet temperature (ºC)	36	38	58	55
Water outlet temperature (ºC)	46	48	68	65
Water flow rate (m^3/h)	28	28	27	29
Water thermal power (kWt)	317	290	330	320
Gross electrical power (kWe)	62,5	59	53	54
Gross electrical efficiency (%)	15,2%	16,0%	13%	14%
Net electrical efficiency (%)	14%	14,8%	11%	12%

ORC prototypes

Expected performance

Global efficiency > 85%

	Generation mode	Cogeneration mode
Thermal oil inlet temperature (ºC)	225	225
Thermal oil outlet temperature (ºC)	130	150
Thermal oil flow rate (m^3/h)	9-11	9-11
Thermal oil thermal power (kWt)	525	435
Water inlet temperature (ºC)	20	60
Water outlet temperature (ºC)	32	70
Water flow rate (m^3/h)	27-31	27-31
Water thermal power (kWt)	405	345
Gross electrical power (kWe)	85	57
Gross electrical efficiency (%)	>16%	>13%
Net electrical efficiency (%)	14,50%	11,50%

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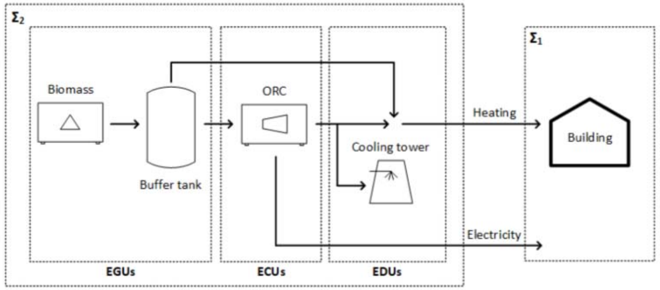
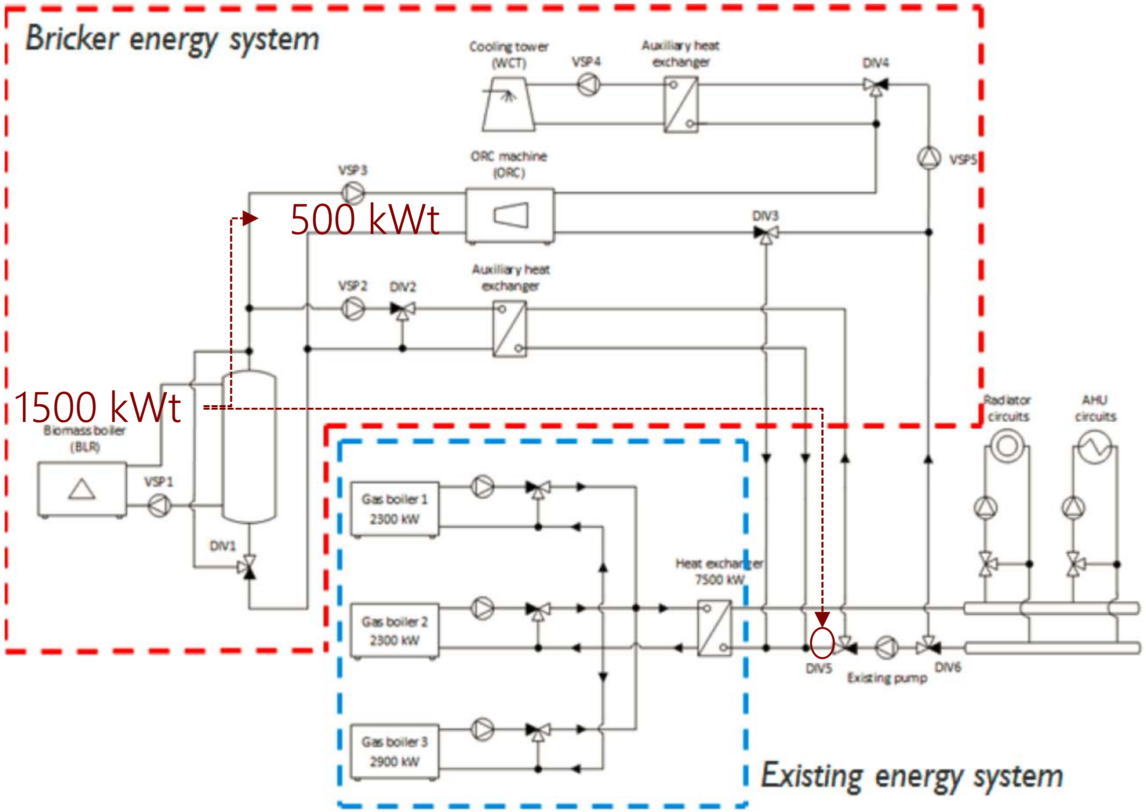
ORC (Integration in Liège)

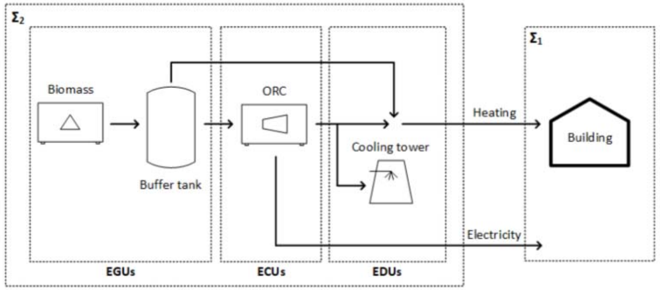


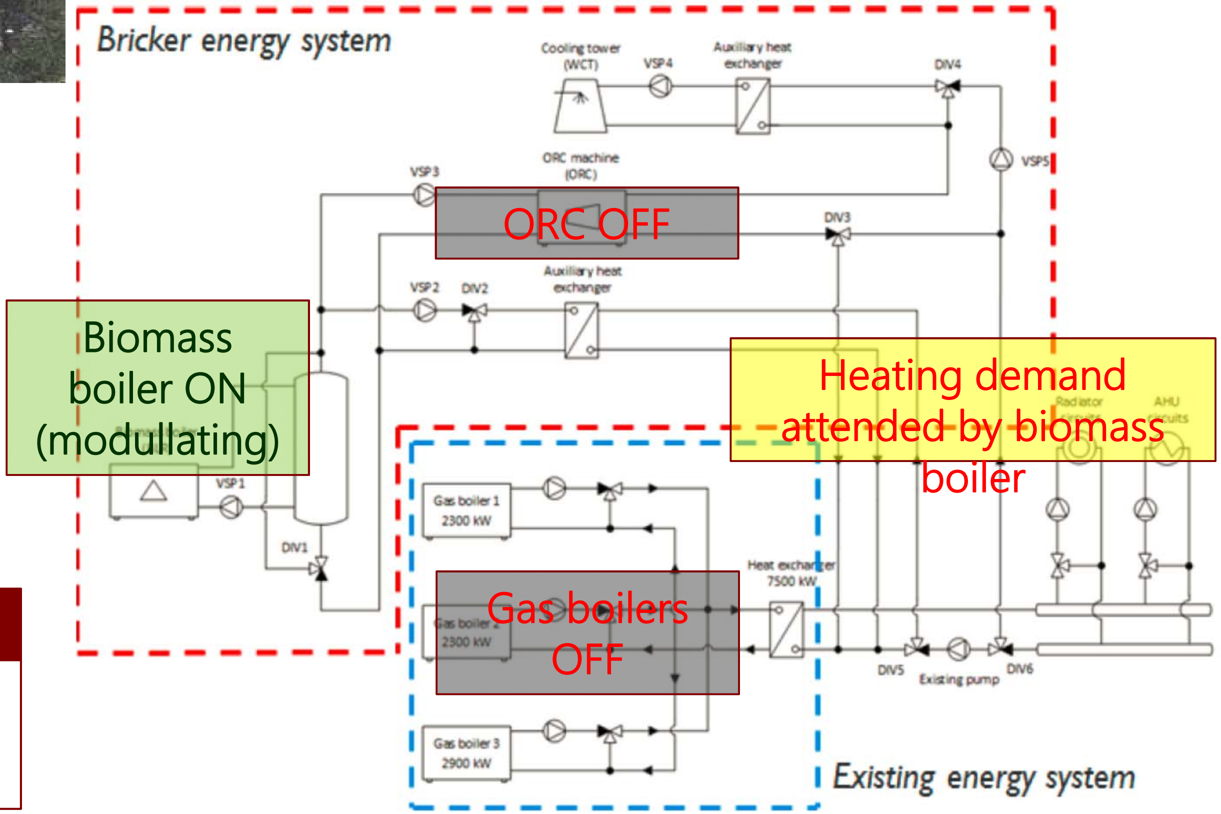
360 kW (Heating)

50 kW (Net Electricity)



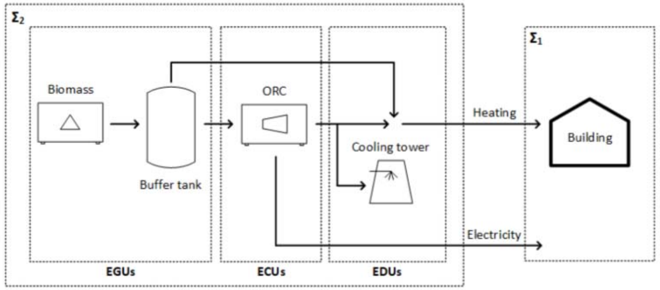
ORC (Integration in Liege) – Heating demand < 360 kWt

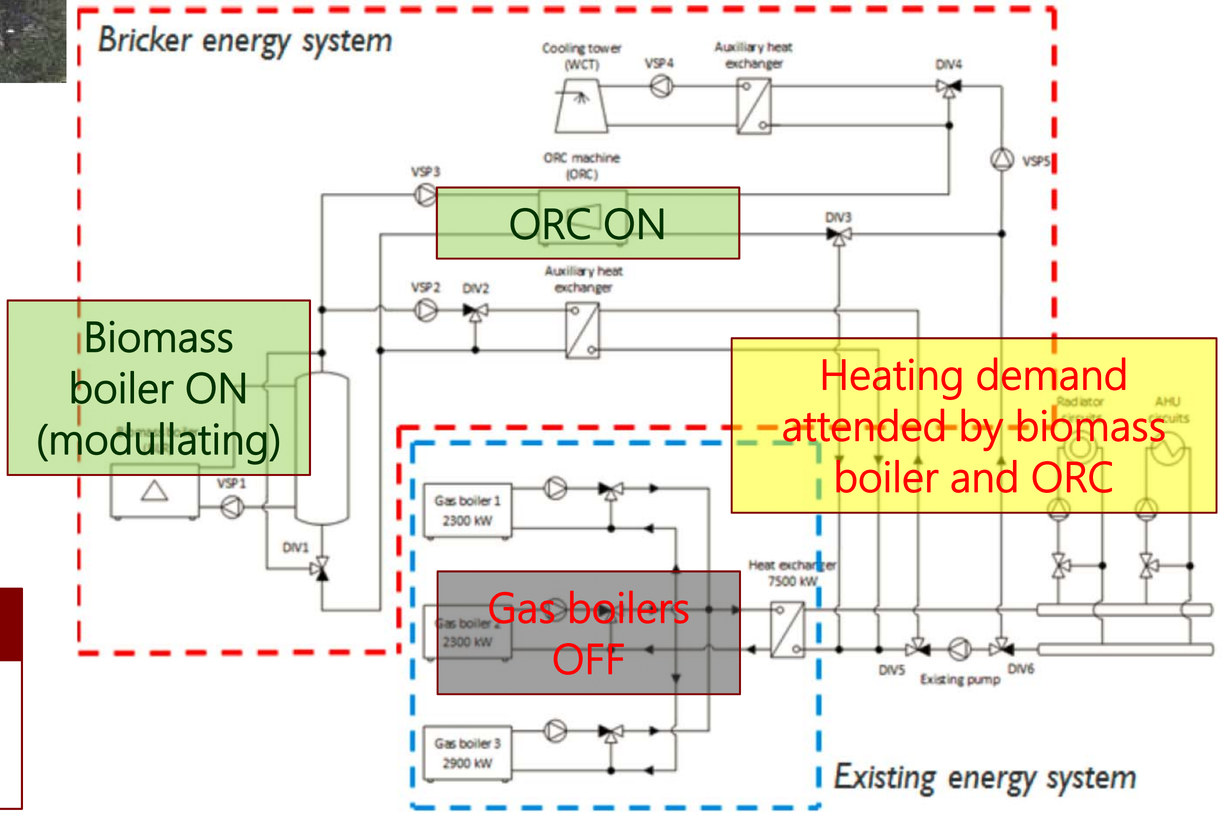




ORC contribution
0 kW (Heating)
0 kW (Net Electricity)

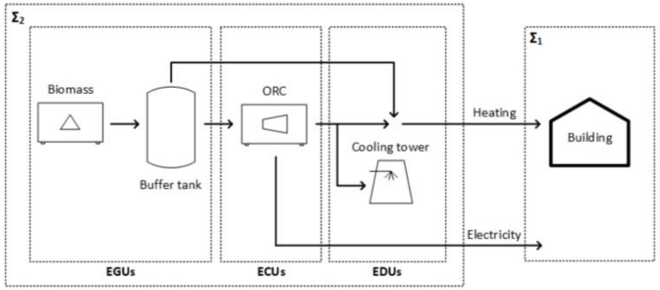
ORC (integration in Liege) – Heating demand [360-1300] kWt

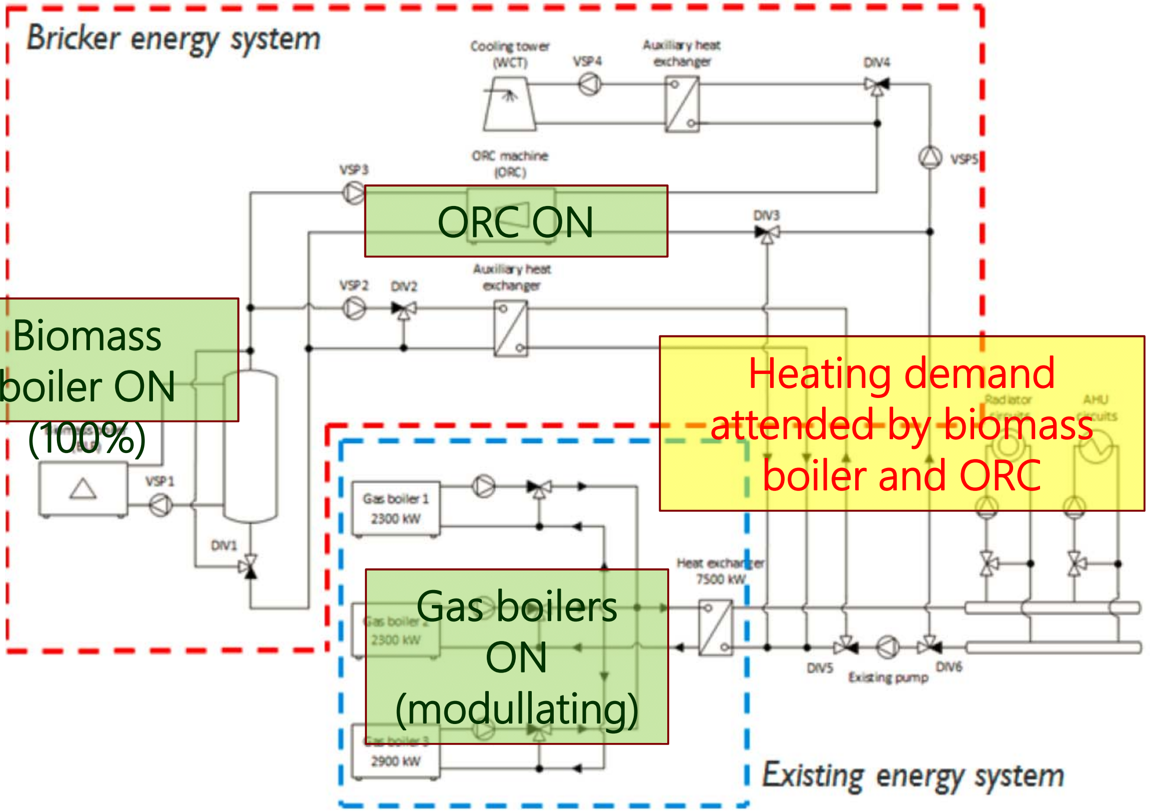




ORC contribution
360 kW (Heating)
50 kW (Net Electricity)

ORC (Integration in Liege) – Heating demand >1300 kWt





ORC ON

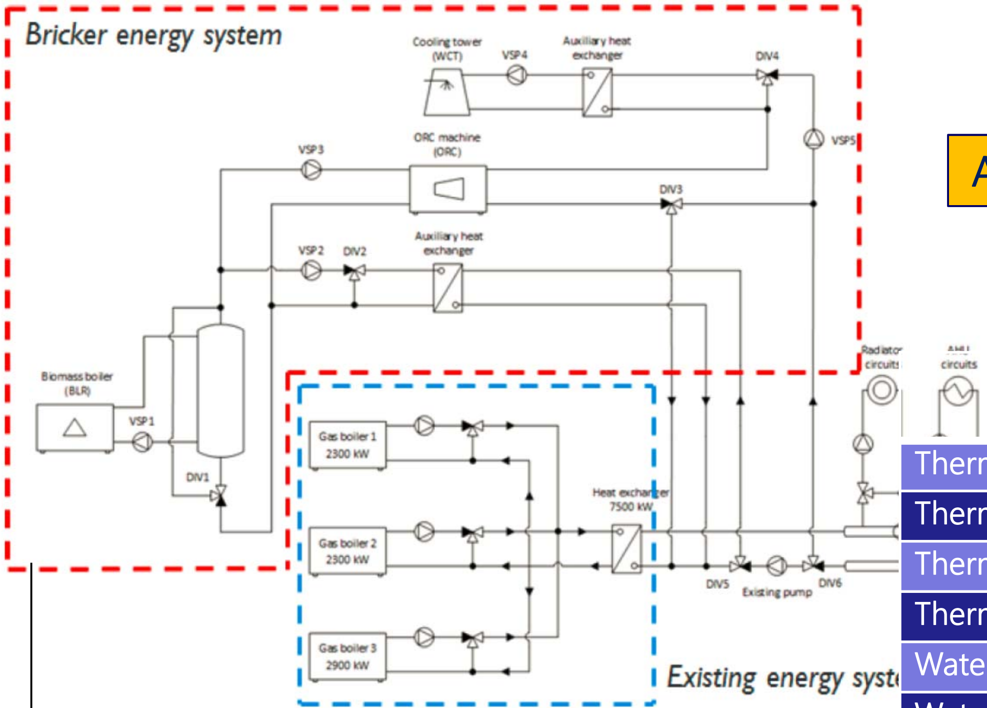
Biomass boiler ON (100%)

Heating demand attended by biomass boiler and ORC

Gas boilers ON (modullating)

ORC contribution
360 kW (Heating)
50 kW (Net Electricity)

ORC Contribution to CO2 emissions reduction - Liège



A reduction of 115 tn CO_2 eq / year

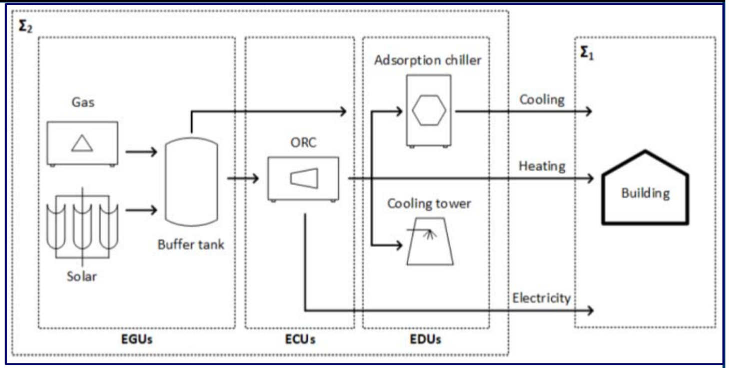
1500 operating hours with heating demand > 360 kWt

540 MWh (Heating)

75 MWh (Net Electricity)

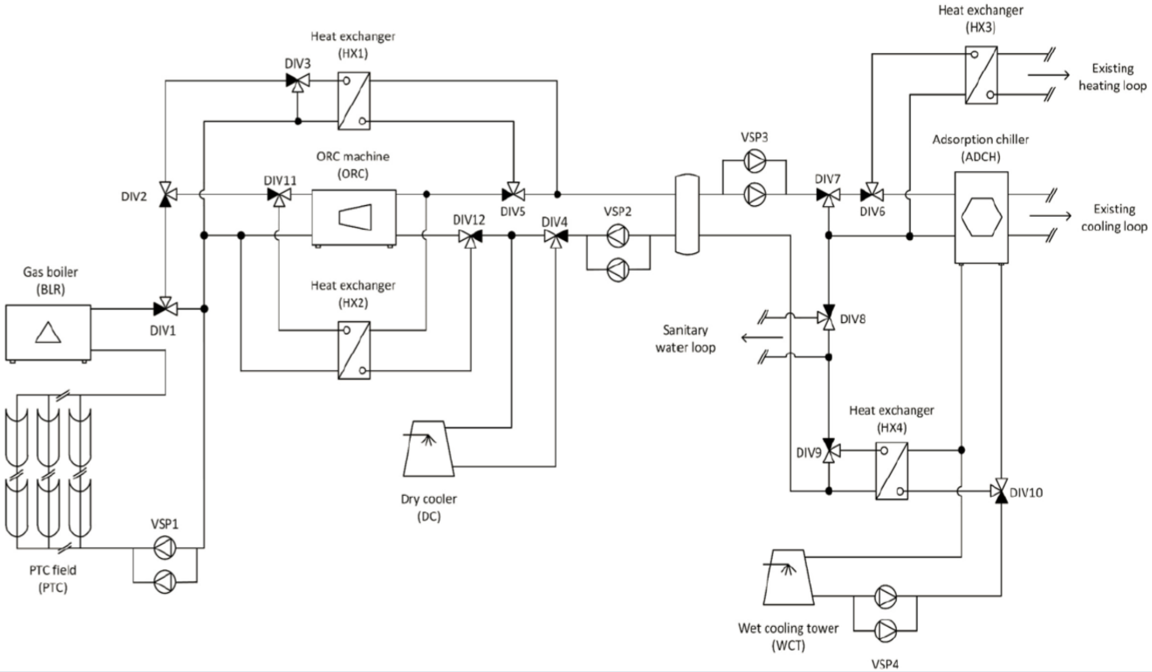
	Cogeneration mode
Thermal oil inlet temperature (ºC)	225
Thermal oil outlet temperature (ºC)	150
Thermal oil flow rate (m³/h)	9-11
Thermal oil thermal power (kWt)	435
Water inlet temperature (ºC)	60
Water outlet temperature (ºC)	70
Water flow rate (m³/h)	27-31
Water thermal power (kWt)	360
Gross electrical power (kWe)	58
Gross electrical efficiency (%)	>13%
Net electrical efficiency (%)	11,50%

ORC (Integration in Turkey)

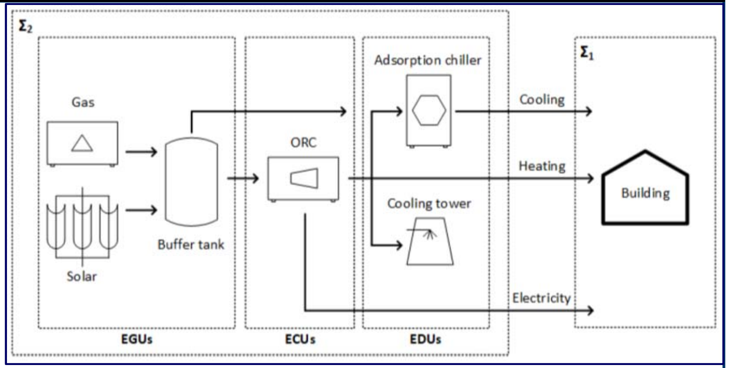


2 x 360 kW (Heating)

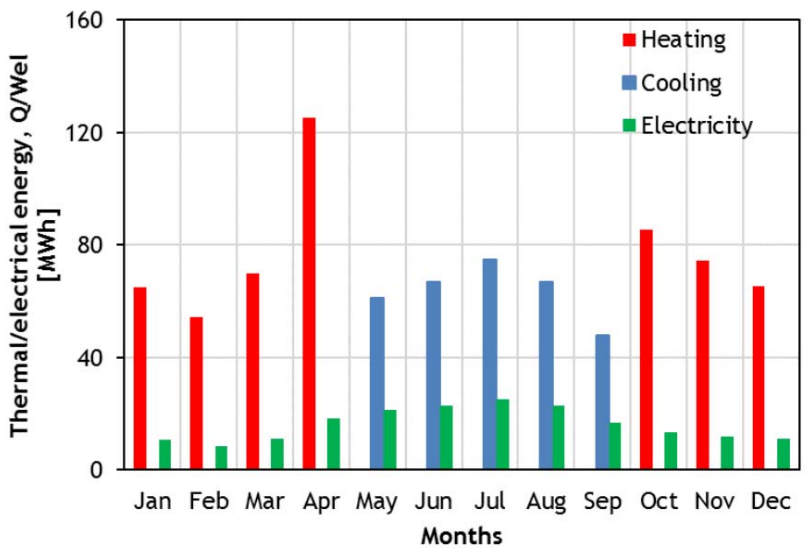
2 x 50 kW (Net Electricity)



ORC (CO_2 emissions reduction) - Turkey



3350 operating hours
541 MWh Heating
318 MWh Cooling
194 MWh Electricity



A reduction of 225 tn CO_2 eq / year

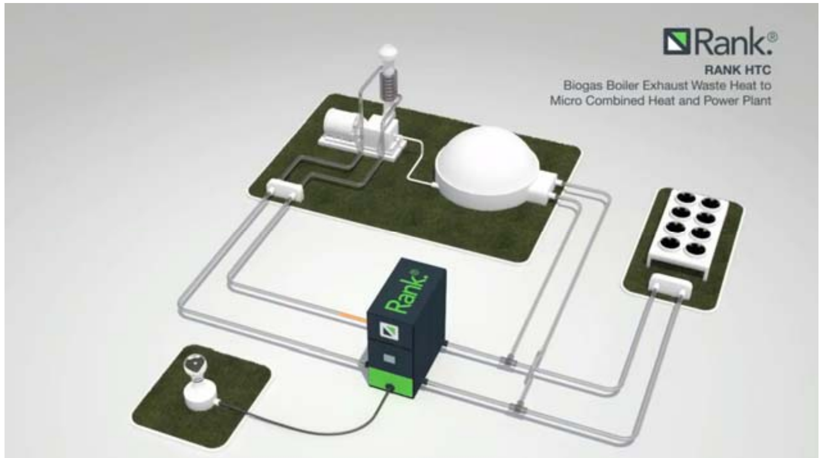
Commercial product (Rank® HTC)

Only cogeneration mode makes sense attending global efficiencies

- Up to 80ºC is a general demand in buildings
- Activation limited up to 210ºC
- Global efficiency [(H+E)/Q] up to 85%

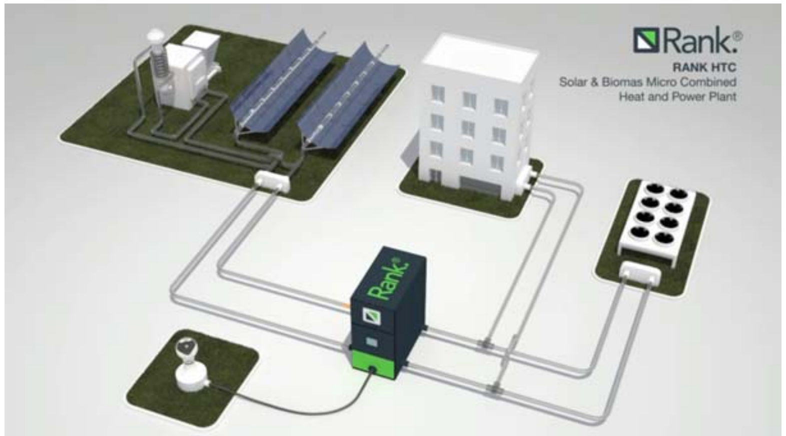
Product	Model	HTC1	HTC2	HTC3
Heat source	Fluid	Thermal oil	Thermal oil	Thermal oil
	Flow rate (m³/h)	12,5	27,0	44,0
	Inlet temperature (ºC)	180-210	180-210	180-210
	Thermal power (kWt)	325-470	690-995	1135-1585
Heat sink	Fluid	Water	Water	Water
	Flow rate (m³/h)	19,0	40,0	65,5
	Inlet temperature (ºC)	45-65	45-65	45-65
	Outlet temperature (ºC)	60-80	60-80	60-80
	Thermal power (kWt)	245-330	515-700	845-1150
Electrical power	Gross power (kWe)	27-43	58-91	95-143

Commercial product (Rank® HTC)



June
2018

September
2017



THANKS…

Any Question?

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